Analysis of the Unsteady Aerodynamics Experiment New Yaw System for National Full-Scale Aerodynamics Complex Testing

Presented to the

National Full-Scale Aerodynamics Complex

by

Jason R. Cotrell, M.S.
The National Wind Technology Center

12/16/99

Introduction

The NWTC has designed a new yaw system for the Unsteady Aerodynamics experiment. The primary benefits of the system are a stronger yaw shaft support structure and yaw drive capability. The new yaw drive system can achieve yaw speeds up to 68/sec--significantly faster than the NFAC turntable speed of .58/sec. This new capability will reduce testing time.

New Yaw System Configuration

The next three figures display the new yaw system components. The analysis of the critical components are presented in Appendix A of this document. The working drawings are presented in Appendix B of this document. A fastener list with the torque specifications are presented in Appendix C.

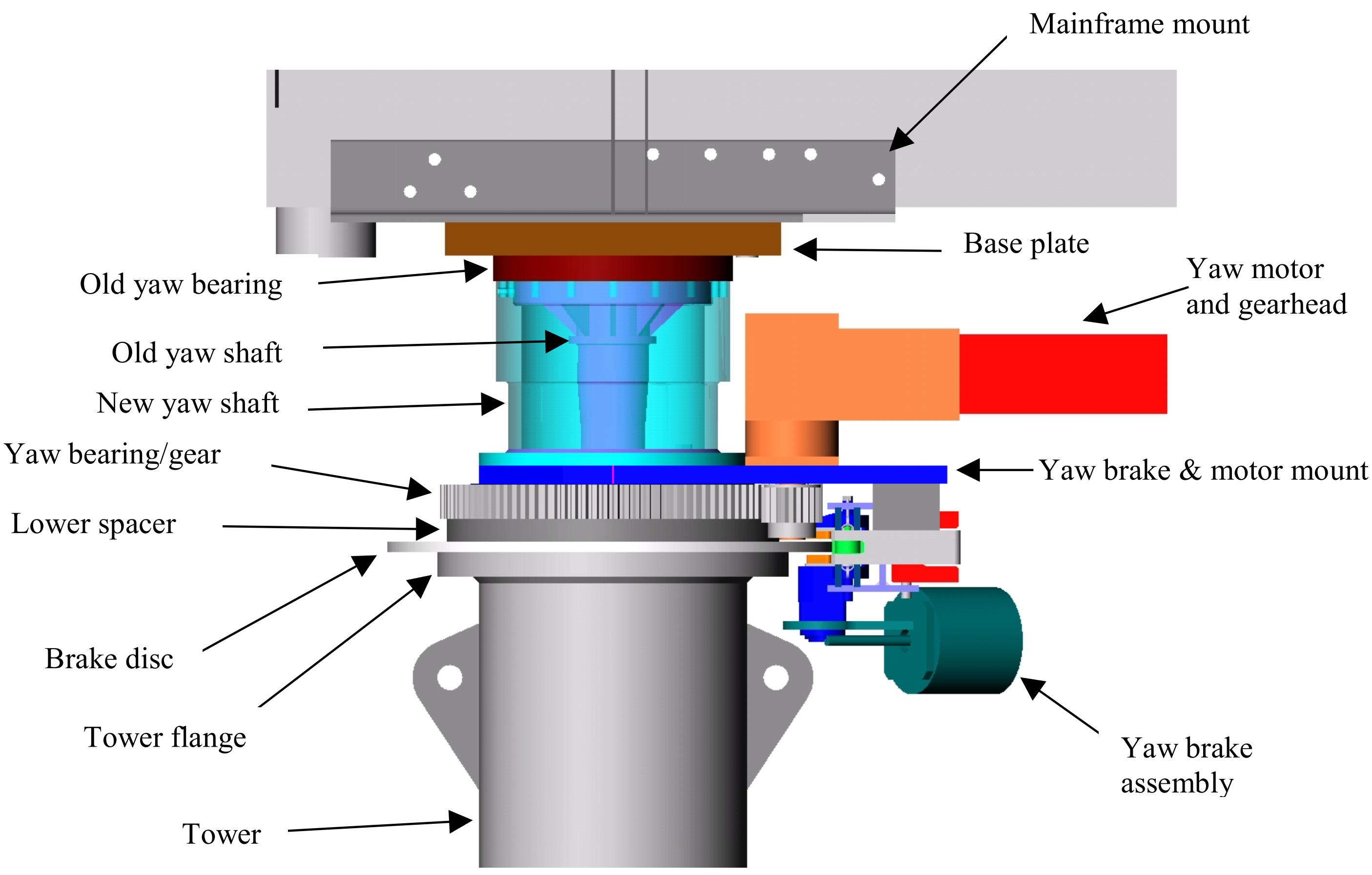

Figure 1: New yaw system components.

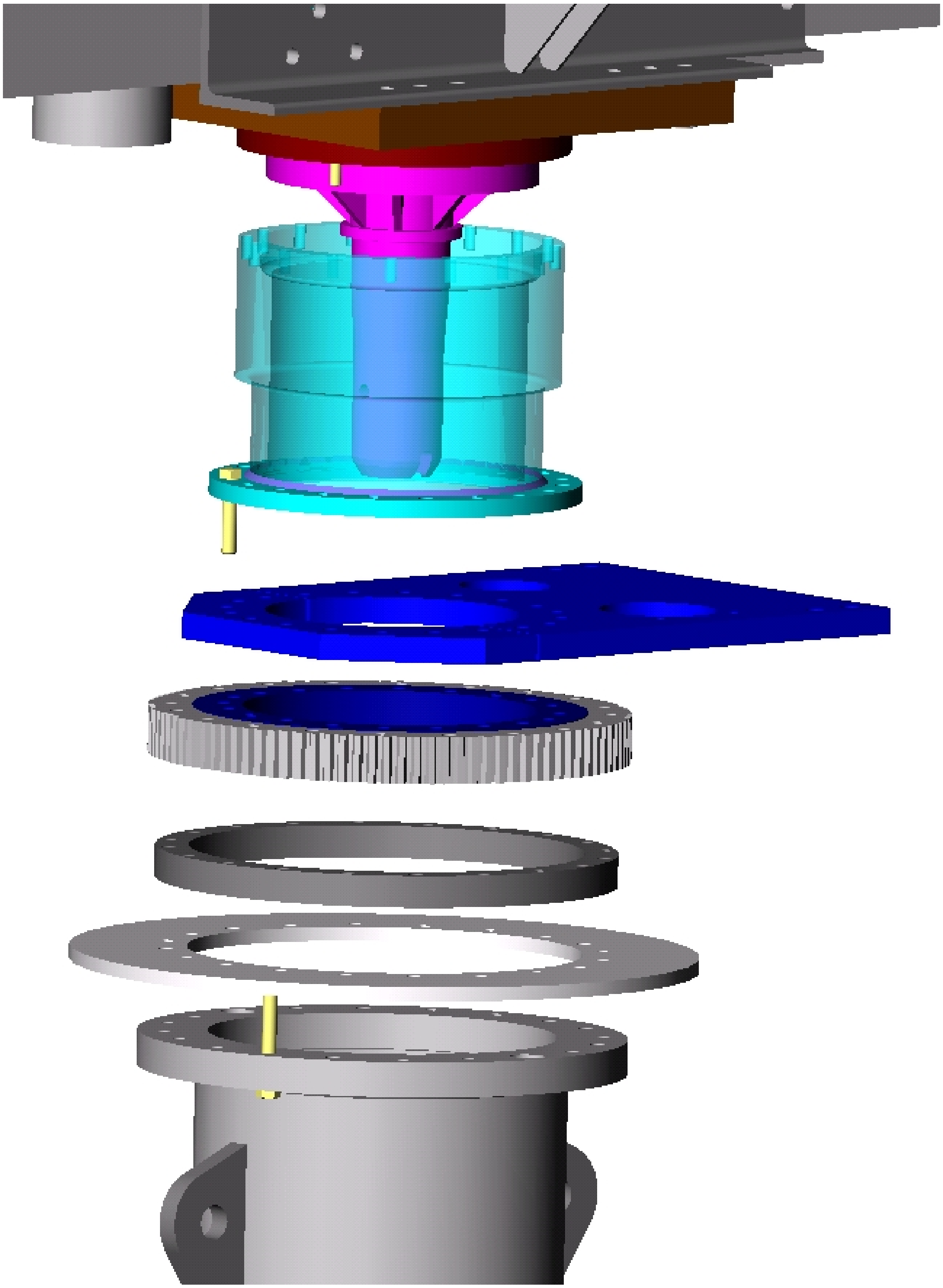

Figure 2: New yaw system critical load path.

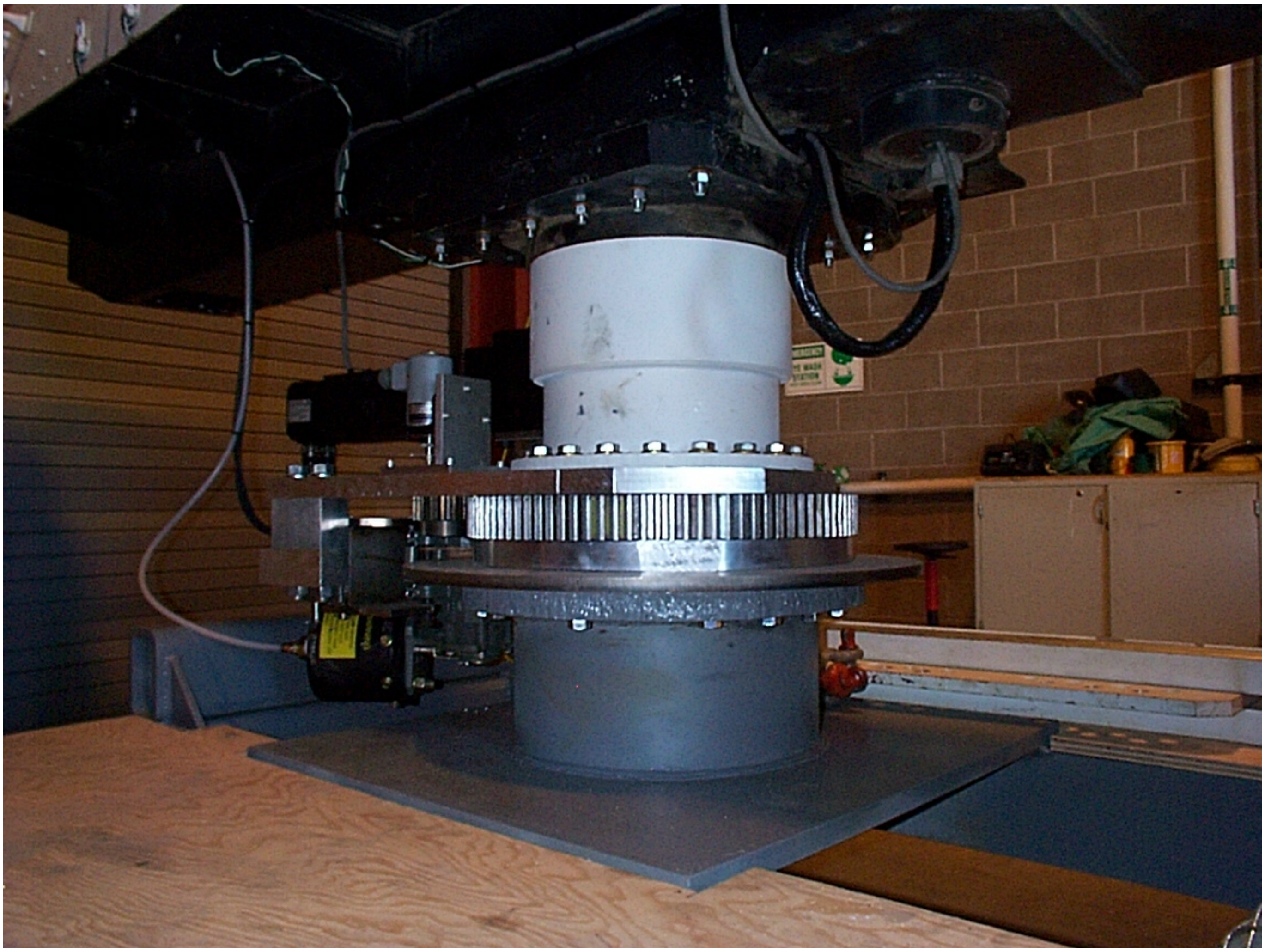

Figure 3: New yaw system photograph.

Old yaw shaft and yaw bearing:

Note that the old yaw shaft and yaw bearing are still in place; however, they have been removed from the load path. It was necessary to leave the old yaw shaft and yaw bearing in place because the droop cable is extremely difficult to remove from the narrow opening in the old yaw shaft.

The old yaw bearing has essentially become a spacer for the new yaw shaft. The outer race of the old yaw bearing is drilled with sixteen ½" through-holes. Hex head cap screws were inserted above the bedplate, through the outer race of the old yaw bearing, and into the new yaw shaft.

The old yaw shaft simply hangs from the inner race of the old yaw bearing. It is free to rotate on old yaw bearing inner race. A tube (not shown) containing the droop cable rotates inside of the old yaw shaft with the nacelle bedplate (and the entire nacelle).

New yaw shaft, yaw brake, and yaw motor:

The new yaw shaft and brake & motor mount rotate on the inner race of the yaw bearing. Twenty 5/8" hex head cap screws were inserted through the new yaw shaft flange, through the yaw brake & motor mount, and screwed into the inner race of the new yaw bearing.

Yaw bearing, lower spacer, brake disc, and tower flange:

The yaw bearing, lower spacer, and brake disc are bolted to the tower flange. Eighteen 5/8" hex head cap screws were inserted from the bottom of the tower flange, through the brake disc and lower spacer, and screwed into the outer race of the new yaw bearing.

Structural Analysis Results

The structural analysis results of the critical components are listed below. The analyses were preformed using MathCad 8.0 and are presented in Appendix A.

Component	Yield Strength Saftey Factor	Ultimate Strength Saftey Factor	Endurance Limit Saftey Factor	Joint Preload Saftey Factor	Thread Pull-Out Yield Saftey Factor
New yaw shaft					
R.25" fillet	7.2	13.4	1.8	-	-
Flange weld	4.2	3.5	1.4	-	-
Upper screws	-	7.2	-	3.4	3.9
Lower screws	-	8.5	-	2.9	18.1
New yaw bearing	5.7	-	-	-	-
Tower flange					
Weld	-	7.7	3.1	-	-
Screws	-	10.1	-	3.4	21.5

The NFAC requires critical components have safety factors of 3.0 against the yield strength and 4.0 against the ultimate strength. All of the components above (excluding the welds) exceed these requirements. In addition, the fatigue analysis indicates that each of the components is expected to have an infinite life. As specified in C6.2 of the NFAC Operations Manual, all welded joints meet ANSI/AWS D1.1-98.

As required by NFAC, each of the joints has at least twice the preload of the operating load. In addition, the fastener strengths exceed NASA's requirement of a safety factor of 4.0 against the ultimate strength. And finally, all tapped threads have at least 1 bolt diameter of thread engagement and the thread pull-out strengths exceed the required 3.0 safety factor against the yield strength.

Appendix A

Yaw System Critical Component Analyses

List of Analyses:

1) Yaw Shaft .25” Fillet Analysis
2) Yaw Shaft Weld Analysis
3) Yaw Shaft Upper Screw Analysis
4) Yaw Shaft Lower Screw Analysis
5) Yaw Bearing Strength Analysis
6) Tower Flange Weld Analysis
7) Tower Flange Screw Analysis

Appendix B

Yaw System Drawings

List of Drawings:

1) Yaw Shaft
2) Yaw Shaft Bottom Flange
3) Yaw Shaft Weldment
4) Yaw Brake & Motor Mount
5) Yaw Bearing / Gear
6) Lower Spacer
7) Brake Disc
8) Tower Flange
9) Tower Flange Weld

Appendix C

Yaw System and Tower Bolt Specifications